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Pore fluid pressure and shear behavior in debris flows of different compositions

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Debris flows are mixtures of sediment and water that can have a wide range of different grain size distributions and water contents. The composition of the material is expected to have a strong effect on the development of pore fluid pressures in excess to hydrostatic, which in turn might affect the internal deformation behavior. We present a set of large scale experiments with debris flow mixtures of different compositions in a 4-m diameter rotating drum. Longitudinal profiles of basal fluid pressure and normal stress were measured and a probe to determine fluid pressure at different depths within the flow was developed and tested. Additionally we determined vertical profiles of mean particle velocities in the flow interior by measuring small variations of conductivity of the passing material and calculating the time lag between signals from two independent measurements at a small, known distance apart. Mean values of basal pore fluid pressure range from hydrostatic pressure for gravel-water flows to nearly complete liquefaction for muddy mixtures having a wide grain size distribution. The data indicate that the presence of fines dampens fluctuations of normalized fluid pressure and normal stress and concentrates shear at the base. The mobility of grain-fluid flows is strongly enhanced by a combination of fines in suspension as part of the interstitial fluid and a wide grain size distribution. Excess fluid pressure may arise from fluid displacement by converging grains at the front of the flow and the slow settling of grains through a highly viscous non-Newtonian fluid. Our findings support the need for pore pressure evolution and diffusion equations in debris flow models as they depend on particle size distributions. This study contributes to the understanding of the production of excess fluid pressure in grain fluid mixtures and may guide the development of constitutive models that describe natural events.